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Design and manufacture portable flatness measuring device

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Abstract
In manufacturing and mechanical engineering, flatness is an important geometric condition for workpieces and tools. Flatness is the condition of a surface or derived median plane having all elements in one plane. In the manufacture of precision parts and assemblies, especially where parts will be required to be connected across a surface area in an air-tight or liquid-tight manner, flatness is a critical quality of the manufactured surfaces. Such surfaces are usually machined or ground to achieve the required degree of flatness. Metrology of such a surface can confirm and ensure that the required degree of flatness has been achieved as a key step in a manufacturing processes. Therefore, measuring flatness becomes very important in mechanical engineering. There have been many different designs of flatness measuring devices. However, designing a compact, handheld flatness measuring device is always a difficulty for design engineers. In this article, the authors propose a plan to design and manufacture a compact, portable flatness measuring device that is very convenient in measuring the flatness of small machine parts.

Keywords: *Flatness, mechanical engineering, workpieces, surfaces, kinematic, measuring flatness.*

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I. INTRODUCTION

Flatness is a measure of a surface's form that indicates whether all of the points along that surface lie in the same plane. Symbolized in Geometric Dimensioning and Tolerancing (GD&T) by a parallelogram, flatness is particularly useful when two surfaces must be assembled together to form a tight seal [5].

The flatness tolerance is determined to ensure that a given surface is located within two imaginary, perfect, and parallel planes. In other words, the tolerance zone is between the highest and lowest acceptable points across the plane of the surface being measured.

Geometric dimensioning and tolerancing has provided geometrically defined, quantitative ways of defining flatness operationally. Flatness deviation may be defined in terms of least squares fit to a plane ("statistical flatness") or worst-case (the distance between the two closest parallel planes within). It can be specified for a given area and/or over an entire surface.

Flatness in GD&T is one of the many engineering tolerancing tools at the disposal of design engineers to control the size and form of their designs. The flatness tolerance is applicable on surfaces whose flatness must be kept within certain bounds for proper part functionality. It is a common way of controlling the form of a surface where flatness is a design requirement [8].

For example, the jaws of a mechanical vice are ground to a highly precise level of flat so that they can grip parts with adequate strength and apply uniform force on the gripped surfaces. In case they are not flat, the grip can be loose and damage the part by inducing stress concentrations.

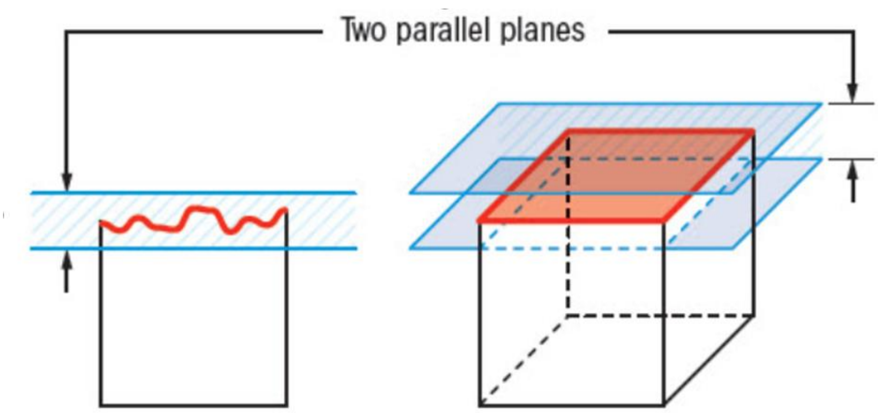

Figure 1: The flatness model with two sets of parallel planes

GD&T Flatness is very straight forward. It is a common symbol that references how flat a surface is regardless of any other datums or features. It comes in useful if a feature is to be defined on a drawing that needs to be uniformly flat without tightening any other dimensions on the drawing. The flatness tolerance references two parallel planes (parallel to the surface that it is called out on) that define a zone where the entire reference surface must lie. Flatness tolerance is always less than the dimensional tolerance associated with it [9].

Measuring flatness consists of analyzing a surface to find how it is not perfectly flat. To do so, the first step is to acquire points on the surface that will allow you to find an envelope of two parallel planes that include all of these points. The next step is finding the smallest possible sandwich of planes, regardless of the orientation (as these planes can move freely in space). The distance between the two furthest points corresponds to the flatness. Therefore, the narrower the space between these two planes, the flatter the plane is [5].

There have been many research papers on flatness measuring device, for example a research on Surface Plate Based Method for Quick Check CMM Accuracy Measurement [1]. A research on Design and Experiment of Precision Flatness Measurement Device for Miniature Parts [2]. A research on Flatness Measurement By Multi-Point Methods And By Scanning Methods [3]. A research on Portable multiscale form measurement technique for structured specular surfaces based on phase measuring deflectometry [4].

In this paper, we present results of research, design and manufacture of a portable flatness measuring device used to measure the flatness of small machine parts outstanding productivity and quality. At the same time, the device is very simple, reducing labor, time and processing costs.

II. THEORITICAL BASIS FOR DESIGN

Flatness is can be measured using a height gauge run across the surface of the part if only the reference feature is held parallel. You are trying making sure that any point along the surface does not go above or below the tolerance zone. Modern CMM's are best for measuring the part as they can create virtual planes that the true surface profile can be compared to. This is a 3D measurement so points must be measured across the length and width of the part to ensure the entire surface is in tolerance. Flatness cannot be measured by simply placing the part on a granite slab and running a height gauge or microheight over it. This would be measuring parallelism instead as you are fixing the bottom of the part as a datum [9].

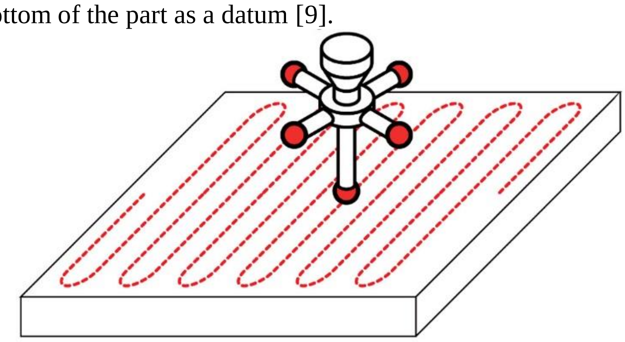

Figure 2: Gauging measurement measure the flatness

Flatness is the 3D version of surface straightness – Instead of the tolerance zone between two lines; the tolerance zone exists between two planes.

When you want to constrain the amount of waviness or variation in a surface without tightening the dimensional tolerance of said surface. Usually, flatness is used to give a surface an even amount of wear or for sealing properly with a mating part. Commonly used on a fixture that must mate flush with another part without wobbling, but where orientation is not important

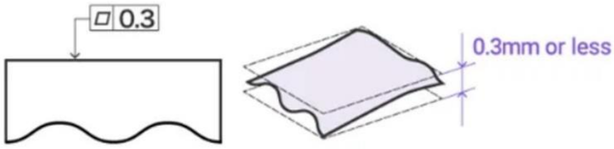

Figure 3: The flatness tolerance zone

The distance between these planes defines the 'tightness' of the flatness tolerance. Based on design intent, the designer sets a tolerance value according to the level of precision required, defining how much room the surface has to deviate from its true form [8].

As said above, the flatness symbol does not require a datum as it does not control the referenced feature against a standard datum feature. That is, it enforces an independent form of tolerance on the surface regardless of its position or orientation with respect to other features in the part.

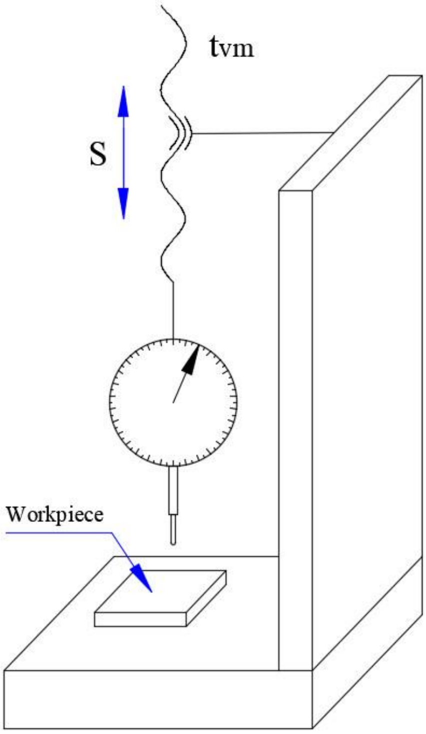

Figure 4: Kinematic diagram of flatness measuring device

The dynamic structure diagram of this device is very simple. Consists of only one forward movement of the dial indicator, this movement takes place during the process of adjusting the device, depending on the thickness of the part whose flatness needs to be measured. The flatness measurement process is performed by moving the part to be measured on the machine table in two directions: Ox and Oy. The flatness will be displayed on the dial indicator.

The flatness measurement process is illustrated with an example of flatness measurement of a 6061 aluminum part as shown below. The operation of moving workpieces is done manually. The flatness of the machined part will be displayed through the display face of the dial indicator.

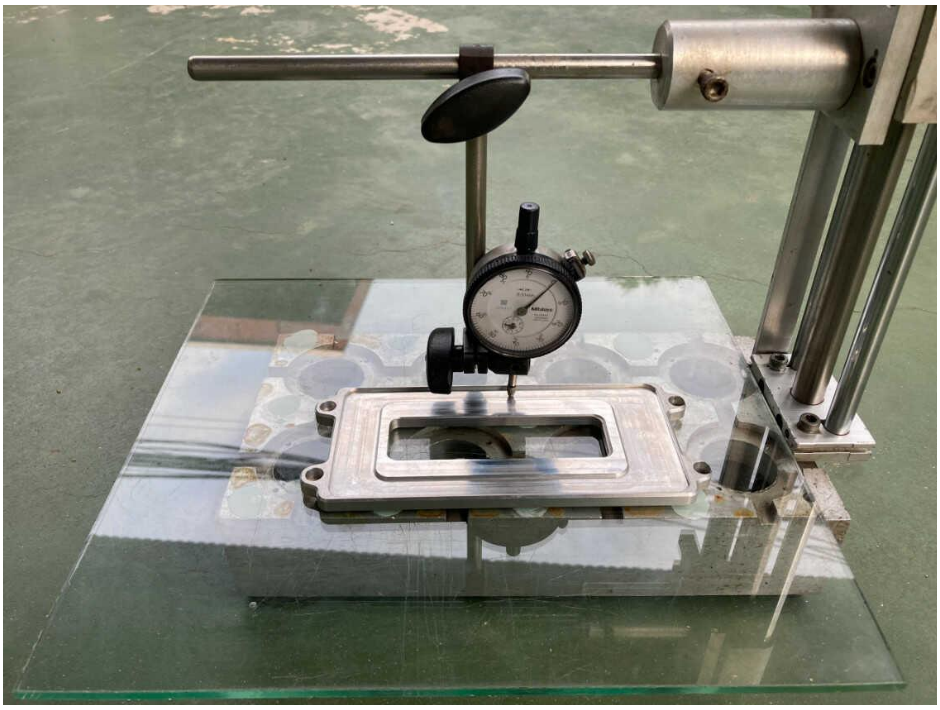

Figure 5: The process of measuring the flatness of workpiece

Figure 6: Step 1

Figure 7: Step 2

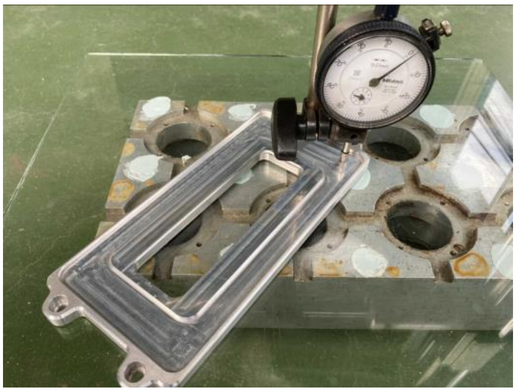

Figure 8: Step 3

Figure 9: Step 4

III. STRUCTURAL DESIGN AND MANUFACTURE OF 3-AXIS PORTABLE MILLING MACHINE

After the kinematic design is completed, the portable flatness measuring device is structurally designed and manufactured, as shown in Figure 10.

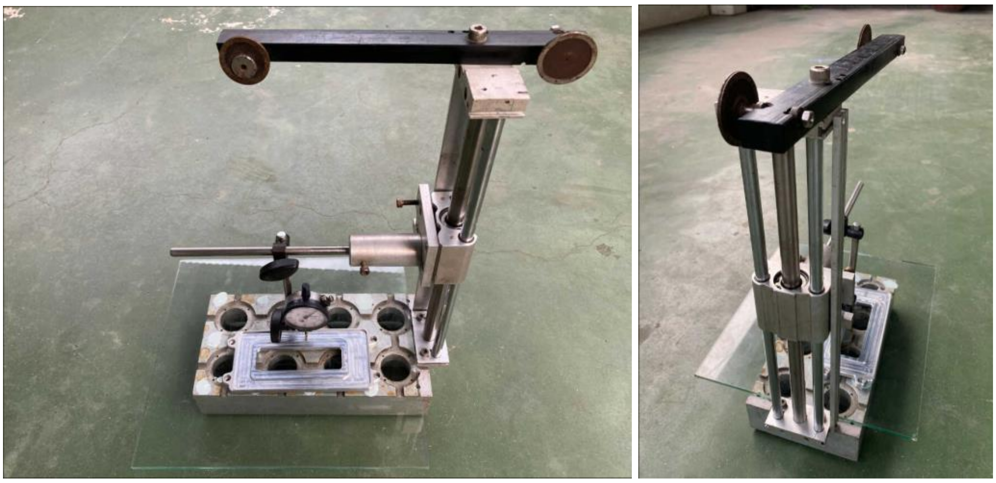

Figure 10: The flatness measuring device

IV. CONCLUSION

The portable flatness measuring device has been researched, designed and manufactured successfully. The device is designed to measuring workpieces at the construction site with outstanding productivity and quality. This helps reducing labor, time and manufaturing costs. The results of the testing processes show that the product meets the initial requirements of the design process. Products that pass the measurement process with this device are fully qualified to meet the flatness requirements during assembly. The study calculated the complete design of the kinematic structure diagram of the flatness measuring device. The results of successful manufacturing of the flatness measuring device and experimental processing with the calculated parameters achieved the right quality as designed.

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